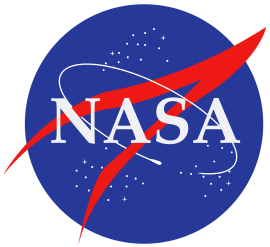


AIRS Applications Status

Sharon Ray, Tom Pagano, Eric Fetzer, Bjorn Lambrigtsen, Joao Teixeira,
Ed Olsen, Steve Licata, Jeff Hall, Charles Thompson
Jet Propulsion Laboratory, California Institute of Technology

Darren Drewry, Stephanie Granger, Ali Behrangi
Jet Propulsion Laboratory, California Institute of Technology

Amir AghaKouchak
University of California, Irvine

Julie Wallace
Environmental Science Researcher

AIRS Spring Science Team Meeting
April 21-23, 2015

Applications Team

Applications Development Lead	Sharon Ray
Applications Science Lead	Bjorn Lambrigtsen
Advisors	Tom Pagano Eric Fetzer Bjorn Lambrigtsen Joao Teixeira
Programmers/Visualizers	Ed Olsen, Steve Licata Jeff Hall, Charles Thompson

Development Pipeline

Concept

Research

Validation

Production

Distribution

Applications – **Concept Phase**

fire weather	• the most influential fire weather originates in the middle and upper troposphere • AIRS data could help determine locations of dry slots and intrusions that contribute to drying and winds.	
MJO climate indicator, weather prediction	• intraseasonal tropical atmospheric oscillation brings periods of enhanced or suppressed rainfall • AIRS data can be used to determine MJO phase/location of oscillations, useful for climate research and weather prediction	
evapotranspiration	• Josh Fisher JPL, algorithm	
pollution distribution, travel, and/or backtrace	• AIRS carbon monoxide	
windchill/coldness index maps - combine with wind data		
flood prediction, early warning system	• determine whether AIRS can give a day or two warning of localized flooding events in the high mountain river valleys of Pakistan/India/ Nepal • look for WV anomalies to find the pre-conditions to such events in the AIRS record • meteorology group that services the region only looks at images, does not have access to WV data. Need easy way to access/analyze data	
meningitis outbreaks	• research on meningitis incidence in sub-Saharan Africa pinpoints wind and dust conditions as predictors of disease	
clear air turbulence		
Kawasaki disease and ENSO	• most common cause of acquired heart disease in children worldwide • may be triggered by windborne agent traveling through winds at midlatitudes • possible link between disease activity and phases of ENSO	
Dzud predictor (Peter Mason, UNICEF)	• Mongolia, severe dry cold winter • dzud devastates herds • cold/dry anomaly maps	• *study: if snow anomalies present early winter, they tend to persist through the entire winter season ...related to ENSO*

Applications – **Research Phase**

Volcanic Ash Burden and Dust • algorithms using AIRS data shown to determine the burden of volcanic ash and distinguish volcanic ash from dust • work is underway to optimize retrievals of dust and volcanic ash heights for use in geophysical retrievals	*Sergio DeSouza-Machado, UMBC* *Vince Realmuto, JPL*
Temperature Inversion Strength for Public Health and Aviation • study using AIRS profiles suggest measurable health effects when inversions occur • thick inversions reported near airports could require aircraft to load more fuel for instrument-only landings (FAA rule) • maps of temperature inversion strength in development for use by health, air quality and weather communities	*Julie Wallace, Environmental Research Consultant* *AIRS JPL science group*
Severe Weather: Deep convective clouds • typically cumulonimbus clouds from Earth's surface to height 10 km (33,000 feet) or higher • can signal areas of large storms • maps of DCC clusters could have utility in aviation industry	*George Aumann, JPL*
AIRS/OCO-2 Data fusion combine AIRS and OCO-2 data to get estimate of CO2 in lower atmosphere	*Amy Braverman, Dave Schimel, JPL*

Applications – **Validation Phase**

Atmospheric Sulfur Dioxide • Fred Prata algorithm (no height information) • L. Yurganov working on improved algorithm at 3 plume heights • V. Realmuto assist with SO2 product validation and development	*Fred Prata, NILU* *Leonid Yurganov, UMBC* *Vince Realmuto, JPL*
Vector Borne Disease • near surface retrievals helping to assess outbreak risk, epidemic potential and identify mosquito incubation periods • dengue fever, malaria, and West Nile virus	*Darren Drewry, JPL*
Drought Indicators • two indicators in validation phase	*Stephanie Granger and Ali Behrangi, JPL* *Amir AghaKouchak and Alireza Farahmand, UC Irvine*
Heat Wave/Comfort Index	*Amir AghaKouchak & Alireza Farahmand, UC Irvine*

Applications – **Production Phase**

Standard Products and Anomalies

Carbon Monoxide, 500hPa	color table approved
Relative Humidity, 500hPa	
Water Vapor, total column	
Temperature, near surface, 500hPa	color table in progress
Ozone, total column	

AIRS climatologies of all products made
from Level 3 three-day running averages

"Let your climatology be your guide"

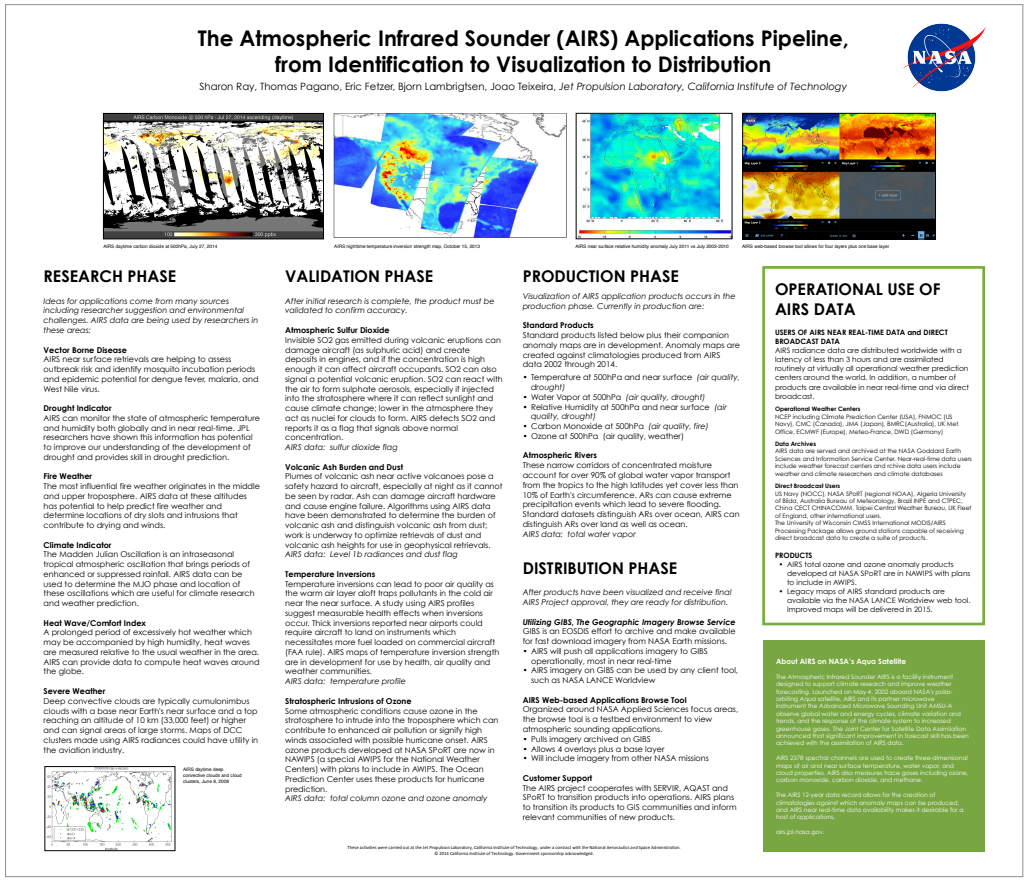
Applications – **Distribution Phase**

Product	**Distribution**
Sulfur Dioxide Flag • AIRS/AMSU SO2 data used operationally by NOAA • notifications of high SO2 concentrations sent to Volcanic Ash Advisory Center • aviation hazard mitigation	**NOAA Volcanic Ash Advisory Center**
Total Column Ozone and Ozone Anomaly • stratospheric intrusions of ozone can signify high winds associated with cyclogenesis • Ocean Prediction Center uses these products for hurricane prediction	**SPoRT AIRS Ozone Products to Ocean Prediction Center** N-AWIPS format: NCEP Advanced Weather Interactive Processing System, special AWIPS for the National Weather Centers
NRT: CO, Dust Score, SO2, Precip Estimate, RH, T	**LANCE Worldview**
***Near Future:* All AIRS Applications Imagery** • AIRS applications imagery archived on GIBS • Geographic Information Systems converter on GIBS • accessible by web clients (WorldView, AIRS Tool)	**EOSDIS GIBS** **Global Imagery Browse Services** core EOSDIS component, provides scalable, responsive, community standards based set of imagery services **AIRS Applications Browse Tool**
AIRS near real-time and direct broadcast data users	
Level 1B	**Operational Weather Centers** *NCEP including Climate Prediction Center (USA), FNMOC (US Navy), CMC (Canada), JMA (Japan), BMRC(Australia), UK Met Office, ECMWF (Europe), Meteo-France, DWD (Germany)*
Level 2	**Direct Broadcast Users** University of Wisconsin CIMSS International MODIS/AIRS Processing Package – ground stations capable of receiving direct broadcast data can create a suite of products **Data Archive DAAC: GES DISC**

Working With Others

NASA Applied Sciences Program	• Director: Laurence Friedl • Program Managers: Health & Air Quality - John Haynes; Disasters: David Green, John Murray (Volcanoes); Fire: Vince Ambrosia • Keep PMs apprised of new applications, maps	
NASA LANCE Land, Atmosphere Near real-time Capability for EOS	• Makes EOS Data from AIRS available within 3 hours • supplies imagery to GIBS, images displayed in NASA Worldview client tool	**Effort underway to coordinate map development**
NASA GES DISC DAAC Goddard Earth Sciences Data and Information Services Center Distributed Active Archive Center	• Possibly serve our Level 4 products • (*in the works*) GIOVANNI visualization tool to automatically create Level 3 imagery to be archived on GIBS	
BEDI Big Earth Data Initiative	• Obama Admin effort to make earth data/ applications accessible • open access and machine readable • improve discoverability, accessibility, usability • support societal benefit areas	
NASA EOSDIS GIBS Global Imagery Browse Services	• archive AIRS application imagery	
NASA SPoRT Short-term Prediction Research and Transition	• Keep apprised of new applications, maps • Will facilitate beta testing in weather field offices	
NASA-USAID SERVIR NASA/USAID joint venture, provides satellite data and science applications to help developing nations improve environmental decision making	• Faisal Hossain (Univ of WA), SERVIR PI: flood warning Nepal/India/ Pakistan • Stephanie Granger (JPL), SERVIR PI: East Africa drought. AIRS drought prediction algorithm with Ali Behrangi	

Getting The Word Out



The Atmospheric Infrared Sounder (AIRS) Applications Pipeline, from Identification to Visualization to Distribution

Sharon Ray, Thomas Pagano, Eric Fetzer, Bjorn Lambrigtsen, Joao Teixeira, *Jet Propulsion Laboratory, California Institute of Technology*

AIRS daytime carbon dioxide at 500hPa, July 27, 2014 | AIRS nighttime temperature inversion strength map, October 15, 2013 | AIRS near surface relative humidity anomaly July 2011 vs July 2003-2010 | AIRS web-based browse tool allows for four layers plus one base layer

RESEARCH PHASE

Ideas for applications come from many sources including researcher suggestion and environmental challenges. AIRS data are being used by researchers in these areas:

Vector Borne Disease
AIRS near surface retrievals are helping to assess outbreak risk and identify mosquito incubation periods and epidemic potential for dengue fever, malaria, and West Nile virus.

Drought Indicator
AIRS can monitor the state of atmospheric temperature and humidity both globally and in near real-time. JPL researchers have shown this information has potential to improve our understanding of the development of drought and provides skill in drought prediction.

Fire Weather
The most influential fire weather originates in the middle and upper troposphere. AIRS data at these altitudes has potential to help predict fire weather and determine locations of dry slots and intrusions that contribute to drying and winds.

Climate Indicator
The Madden Julian Oscillation is an intraseasonal tropical atmospheric oscillation that brings periods of enhanced or suppressed rainfall. AIRS data can be used to determine the MJO phase and location of these oscillations which are useful for climate research and weather prediction.

Heat Wave/Comfort Index
A prolonged period of excessively hot weather which may be accompanied by high humidity, heat waves are measured relative to the usual weather in the area. AIRS can provide data to compute heat waves around the globe.

Severe Weather
Deep convective clouds are typically cumulonimbus clouds with a base near Earth's near surface and a top reaching an altitude of 10 km (33,000 feet) or higher and can signal areas of large storms. Maps of DCC clusters made using AIRS radiances could have utility in the aviation industry.

AIRS daytime deep convective clouds and cloud clusters, June 8, 2008

VALIDATION PHASE

After initial research is complete, the product must be validated to confirm accuracy.

Atmospheric Sulfur Dioxide
Invisible SO2 gas emitted during volcanic eruptions can damage aircraft (as sulphuric acid) and create deposits in engines, and if the concentration is high enough it can affect aircraft occupants. SO2 can also signal a potential volcanic eruption. SO2 can react with the air to form sulphate aerosols, especially if injected into the stratosphere where it can reflect sunlight and cause climate change; lower in the atmosphere they act as nuclei for clouds to form. AIRS detects SO2 and reports it as a flag that signals above normal concentration.
AIRS data: sulfur dioxide flag

Volcanic Ash Burden and Dust
Plumes of volcanic ash near active volcanoes pose a safety hazard to aircraft, especially at night as it cannot be seen by radar. Ash can damage aircraft hardware and cause engine failure. Algorithms using AIRS data have been demonstrated to determine the burden of volcanic ash and distinguish volcanic ash from dust; work is underway to optimize retrievals of dust and volcanic ash heights for use in geophysical retrievals.
AIRS data: Level 1b radiances and dust flag

Temperature Inversions
Temperature inversions can lead to poor air quality as the warm air layer aloft traps pollutants in the cold air near the near surface. A study using AIRS profiles suggest measurable health effects when inversions occur. Thick inversions reported near airports could require aircraft to land on instruments which necessitates more fuel loaded on commercial aircraft (FAA rule). AIRS maps of temperature inversion strength are in development for use by health, air quality and weather communities.
AIRS data: temperature profile

Stratospheric Intrusions of Ozone
Some atmospheric conditions cause ozone in the stratosphere to intrude into the troposphere which can contribute to enhanced air pollution or signify high winds associated with possible hurricane onset. AIRS ozone products developed at NASA SPoRT are now in NAWIPS (a special AWIPS for the National Weather Centers) with plans to include in AWIPS. The Ocean Prediction Center uses these products for hurricane prediction.
AIRS data: total column ozone and ozone anomaly

PRODUCTION PHASE

Visualization of AIRS application products occurs in the production phase. Currently in production are:

Standard Products
Standard products listed below plus their companion anomaly maps are in development. Anomaly maps are created against climatologies produced from AIRS data 2002 through 2014.

- Temperature at 500hPa and near surface *(air quality, drought)*
- Water Vapor at 500hPa *(air quality, drought)*
- Relative Humidity at 500hPa and near surface *(air quality, drought)*
- Carbon Monoxide at 500hPa *(air quality, fire)*
- Ozone at 500hPa *(air quality, weather)*

Atmospheric Rivers
These narrow corridors of concentrated moisture account for over 90% of global water vapor transport from the tropics to the high latitudes yet cover less than 10% of Earth's circumference. ARs can cause extreme precipitation events which lead to severe flooding. Standard datasets distinguish ARs over ocean. AIRS can distinguish ARs over land as well as ocean.
AIRS data: total water vapor

DISTRIBUTION PHASE

After products have been visualized and receive final AIRS Project approval, they are ready for distribution.

Utilizing GIBS, The Geographic Imagery Browse Service
GIBS is an EOSDIS effort to archive and make available for fast download imagery from NASA Earth missions.

- AIRS will push all applications imagery to GIBS operationally, most in near real-time
- AIRS imagery on GIBS can be used by any client tool, such as NASA LANCE Worldview

AIRS Web-based Applications Browse Tool
Organized around NASA Applied Sciences focus areas, the browse tool is a testbed environment to view atmospheric sounding applications.

- Pulls imagery archived on GIBS
- Allows 4 overlays plus a base layer
- Will include imagery from other NASA missions

Customer Support
The AIRS project cooperates with SERVIR, AQAST and SPoRT to transition products into operations. AIRS plans to transition its products to GIS communities and inform relevant communities of new products.

OPERATIONAL USE OF AIRS DATA

USERS OF AIRS NEAR REAL-TIME DATA and DIRECT BROADCAST DATA
AIRS radiance data are distributed worldwide with a latency of less than 3 hours and are assimilated routinely at virtually all operational weather prediction centers around the world. In addition, a number of products are available in near real-time and via direct broadcast.

Operational Weather Centers
NCEP including Climate Prediction Center (USA), FNMOC (US Navy), CMC (Canada), JMA (Japan), BMRC(Australia), UK Met Office, ECMWF (Europe), Meteo-France, DWD (Germany)

Data Archives
AIRS data are served and archived at the NASA Goddard Earth Sciences and Information Service Center. Near-real-time data users include weather forecast centers and ichive data users include weather and climate researchers and climate databases

Direct Broadcast Users
US Navy (NOCC), NASA SPoRT (regional NOAA), Algeria University of Blida, Australia Bureau of Meteorology, Brazil INPE and CPTEC, China CECT CMA/ACOMM, Taipei Central Weather Bureau, UK Fleet of England, other international users.
The University of Wisconsin CIMSS International MODIS/AIRS Processing Package allows ground stations capable of receiving direct broadcast data to create a suite of products.

PRODUCTS

- AIRS total ozone and ozone anomaly products developed at NASA SPoRT are in NAWIPS with plans to include in AWIPS.
- Legacy maps of AIRS standard products are available via the NASA LANCE Worldview web tool. Improved maps will be delivered in 2015.

About AIRS on NASA's Aqua Satellite

The Atmospheric Infrared Sounder AIRS is a facility instrument designed to support climate research and improve weather forecasting. Launched on May 4, 2002 aboard NASA's polar-orbiting Aqua satellite. AIRS and its partner microwave instrument the Advanced Microwave Sounding Unit-A(AMSU-A observe global water and energy cycles, climate variation and trends, and the response of the climate system to increased greenhouse gases. The Joint Center for Satellite Data Assimilation announced that significant improvement in forecast skill has been achieved with the assimilation of AIRS data.

AIRS 2378 spectral channels are used to create three-dimensional maps of air and near surface temperature, water vapor, and cloud properties. AIRS also measures trace gases including ozone, carbon monoxide, carbon dioxide, and methane.

The AIRS 12-year data record allows for the creation of climatologies against which anomaly maps can be produced, and AIRS near real-time data availability makes it desirable for a host of applications.

These activities were carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

AGU Fall 2014 poster

"Near-Real-Time Data for Earth Science and Space Weather Applications"

95th AMS Annual Meeting

talk

"Sixth Conference on Environment and Health"

1. Temperature inversions: Study using AIRS profiles suggest measurable health effects when inversions occur
   Researcher Julie Wallace, McMaster University, environmental consultant
   "*Atmospheric remote sensing to detect effects of temperature inversions on sputum cell counts in airway diseases*", Environmental Research 110 (2010) 624–632
2. Vector Borne Disease
3. Drought Indicators
4. Volcanic Ash

Making Maps

Rapidly Prototyping the Color Bar

Utilize 3-Day Running Avg Climatologies

- Report mins and maxes for quick first take on color bar scale

Photoshop Trick: Using gradient maps

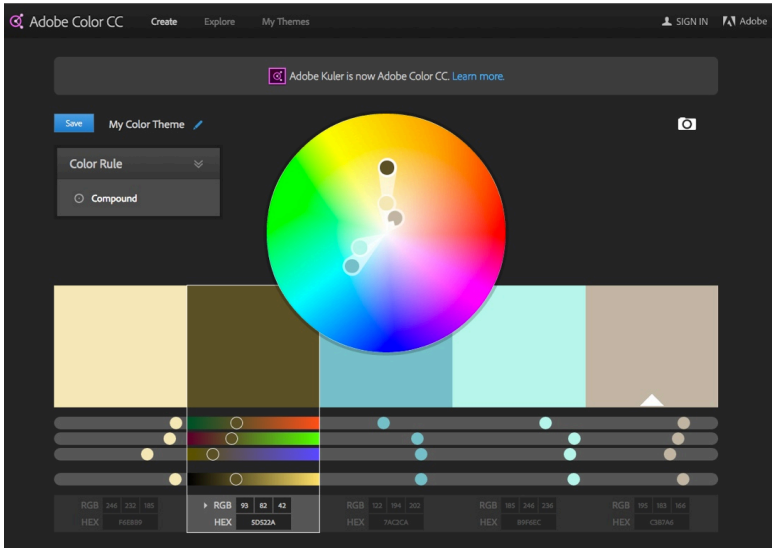
- Dan Pisut, Environmental Visualization Program Manager, NOAA
- paint color on grayscale RGB versions of the image
- significantly cuts down development time
- infinite possibilities, try anything quickly
- smoothing

NCAR Color Gallery

http://www.ncl.ucar.edu/Document/Graphics/color_table_gallery.shtml

Adobe Kuler

https://color.adobe.com



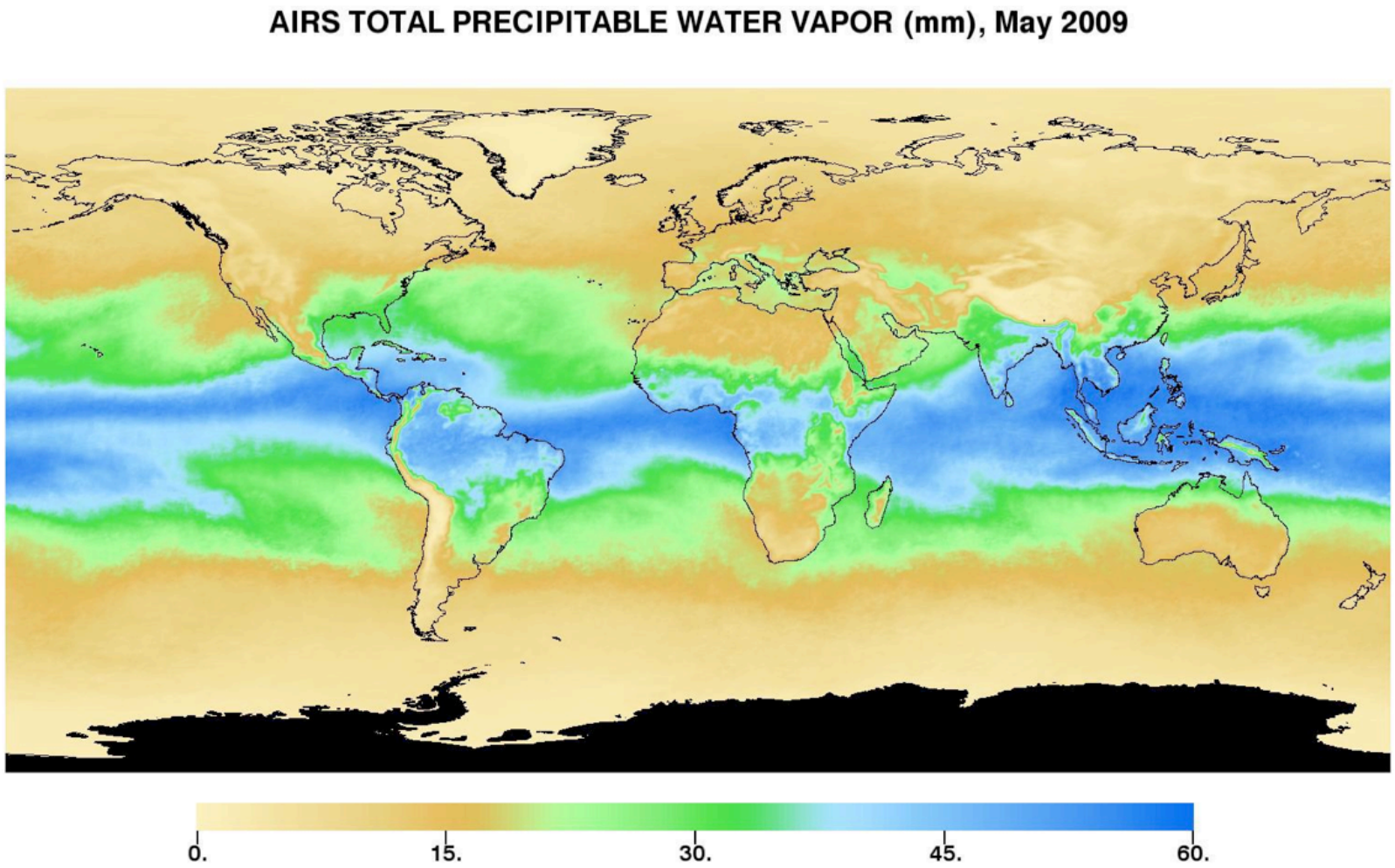
Map Making Considerations

What do we want the data to communicate?

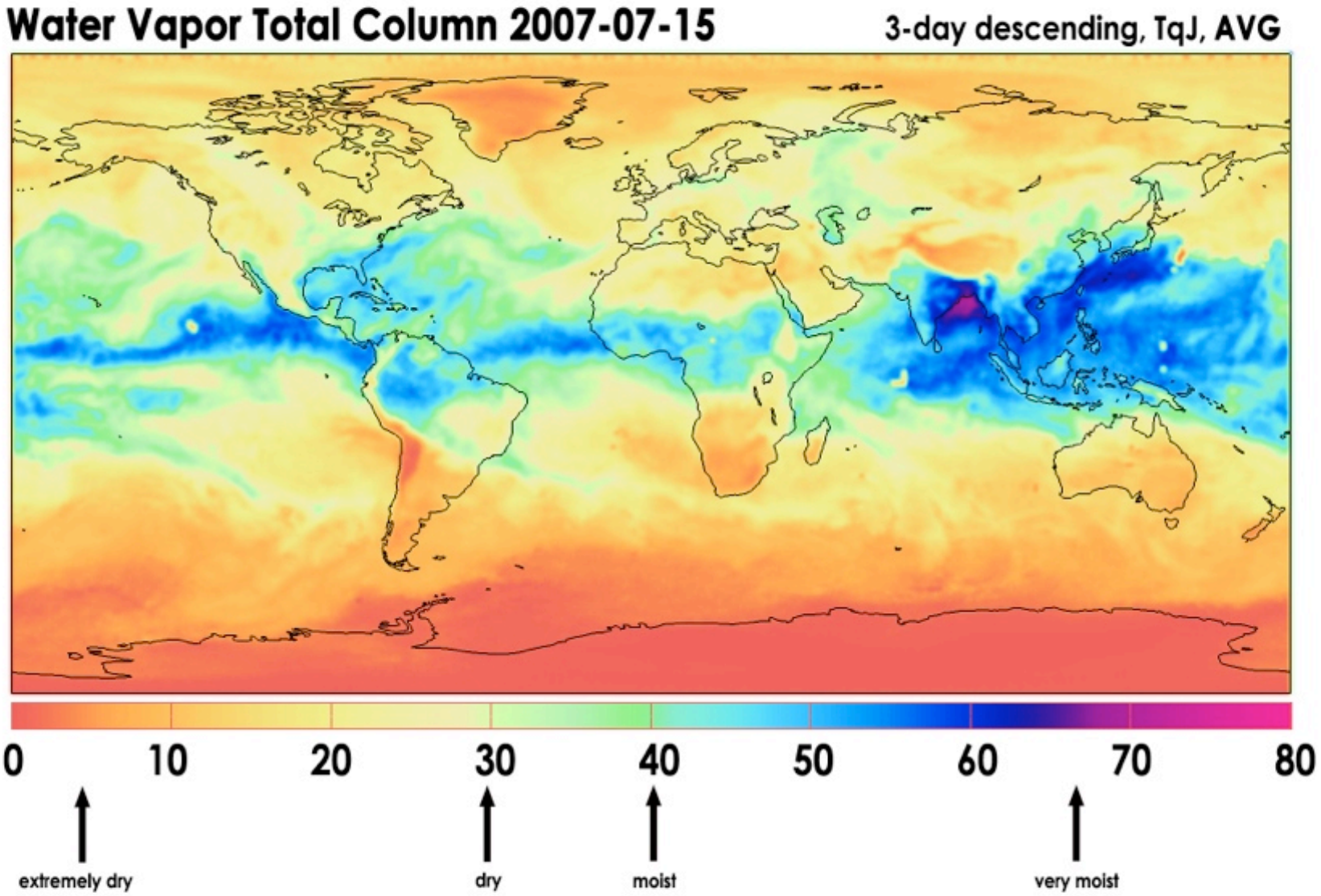
Does the map "feel" like the measurement?

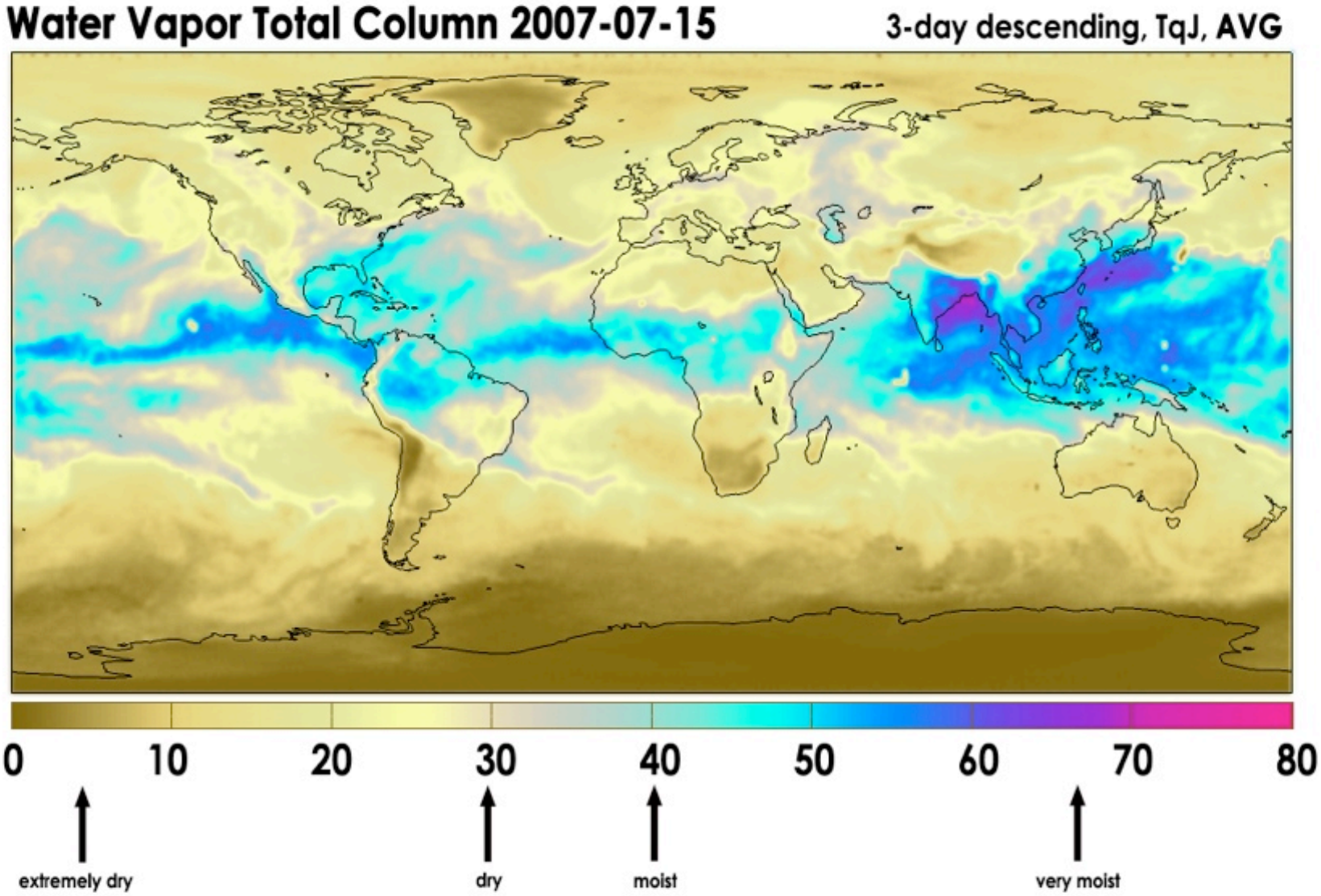
Does it look great?

Map Making – **Previous Water Vapor, total column**

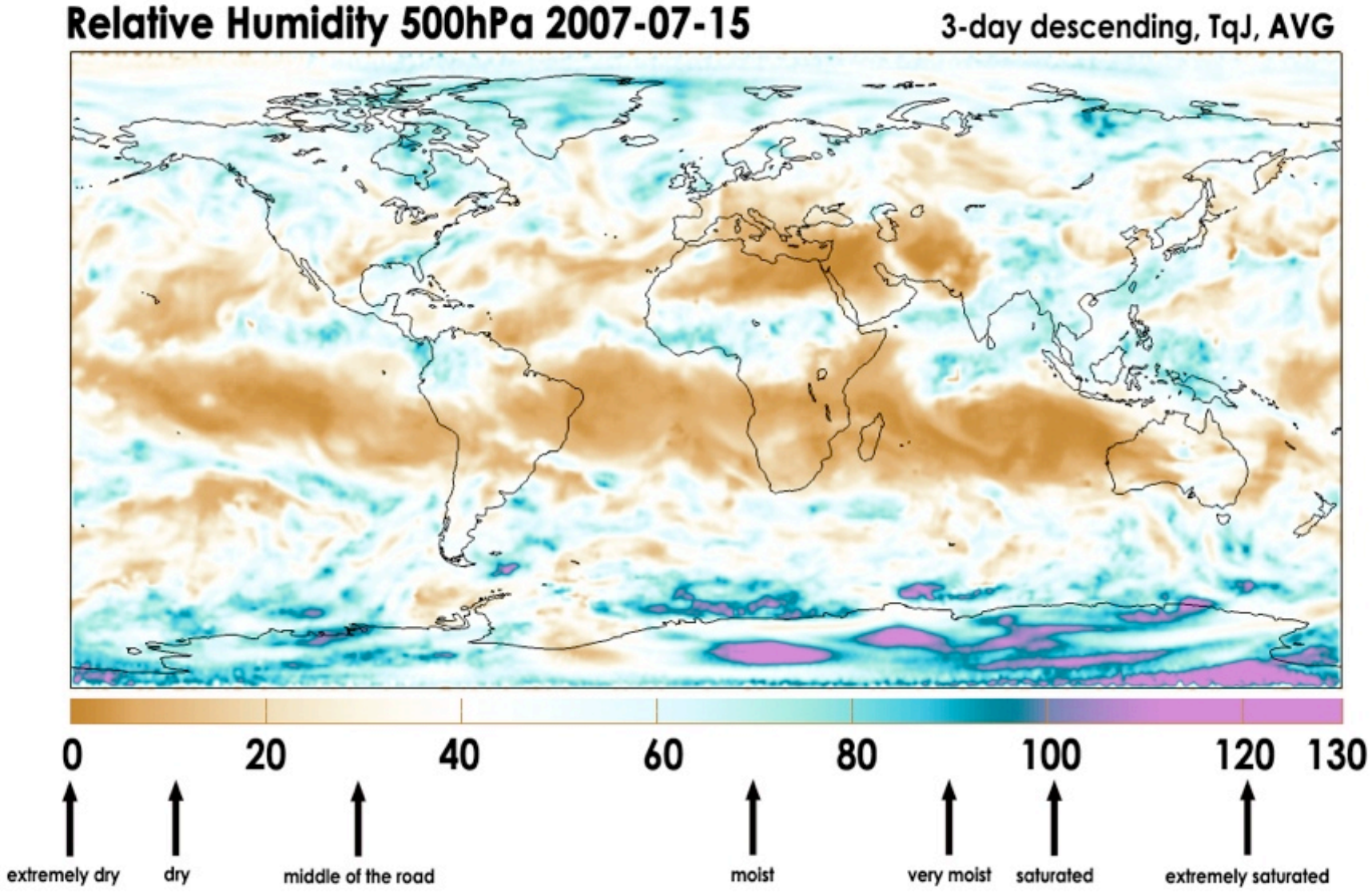


Map Making – **new iterations**

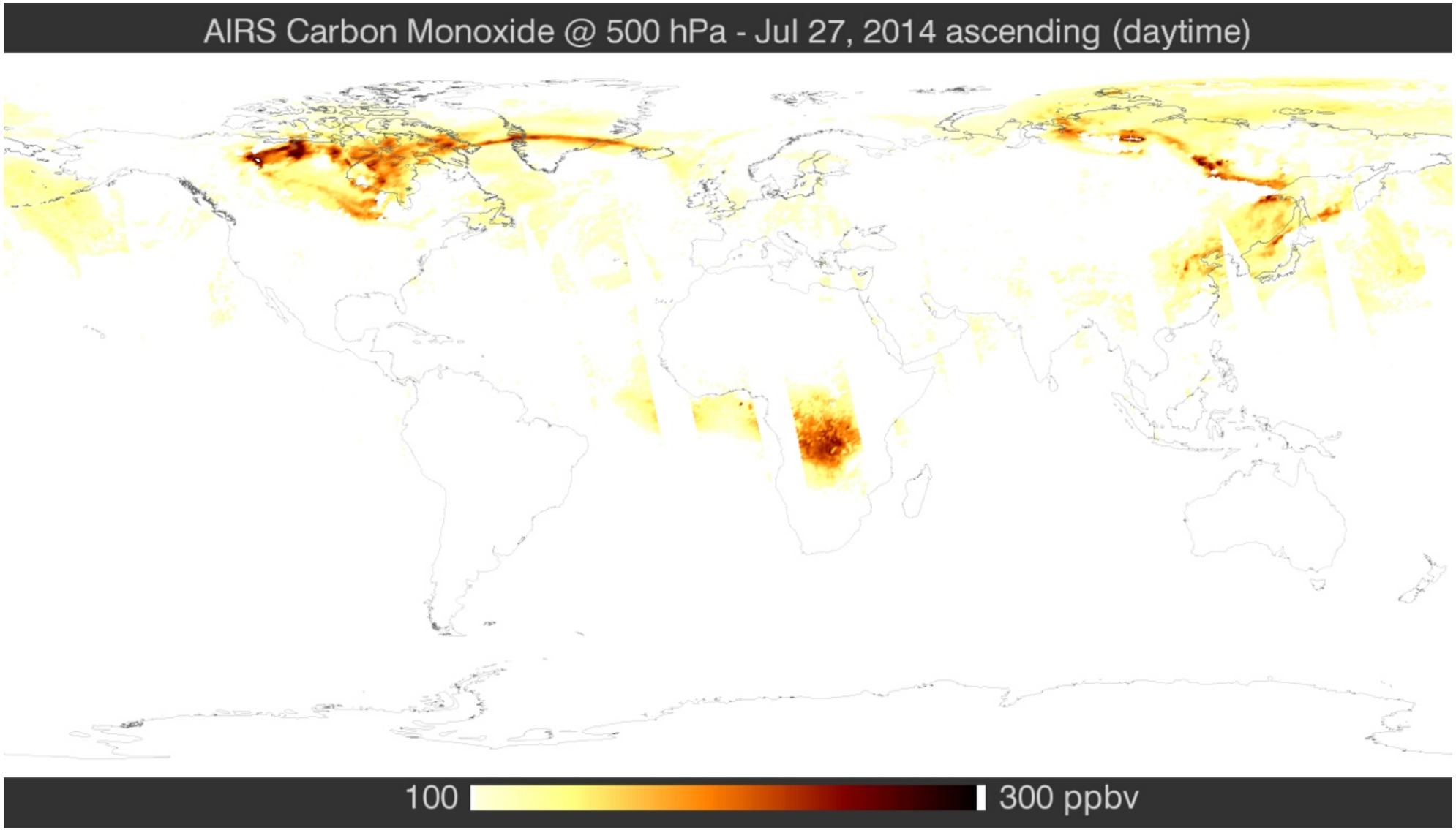



Water Vapor Total Column 2007-07-15
3-day descending, TqJ, AVG
0
10
20
30
40
50
60
70
80
extremely dry
dry
moist
very moist

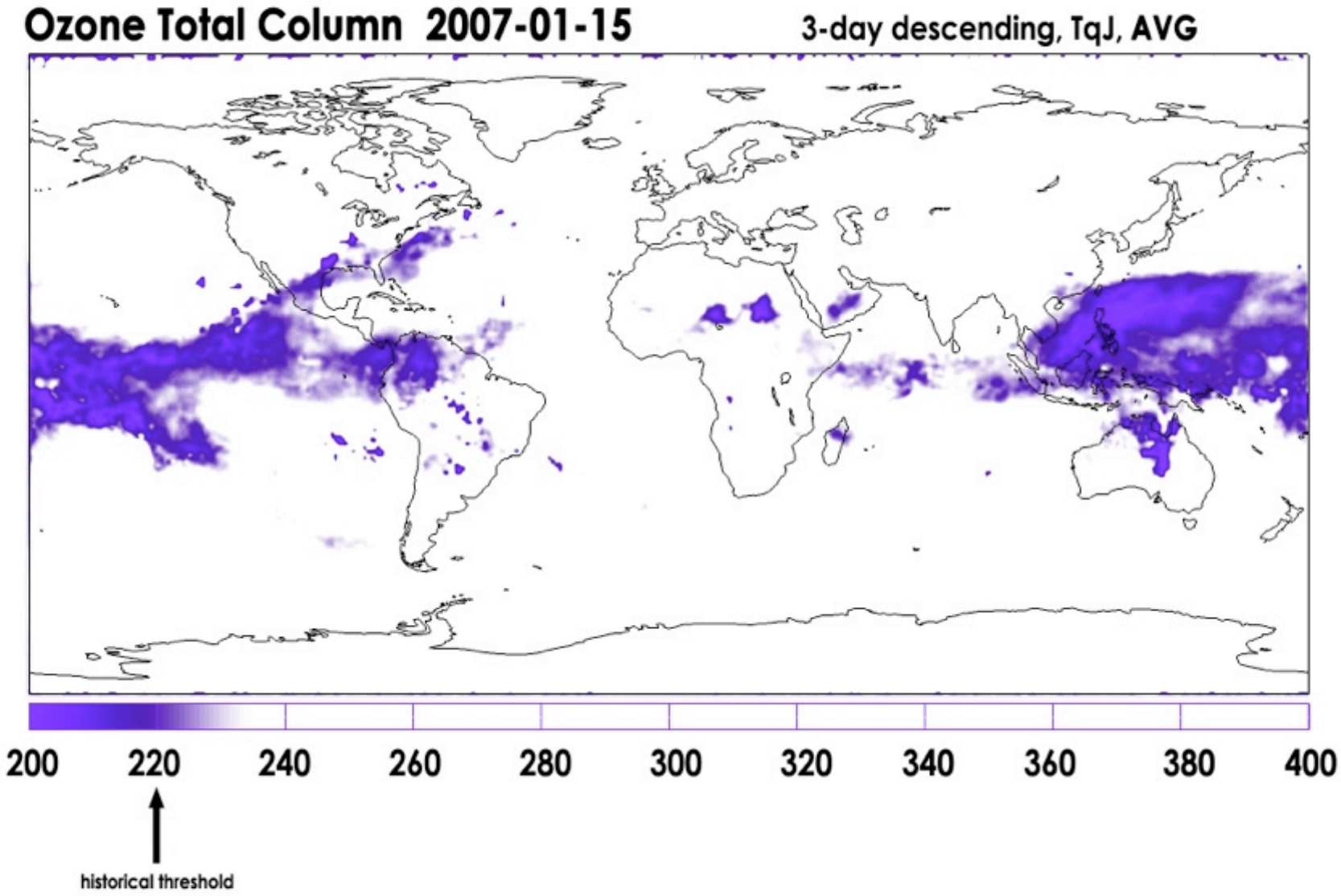
Map Making – **Relative Humidity @500hPa**



Map Making – **Carbon Monoxide @500hPa**

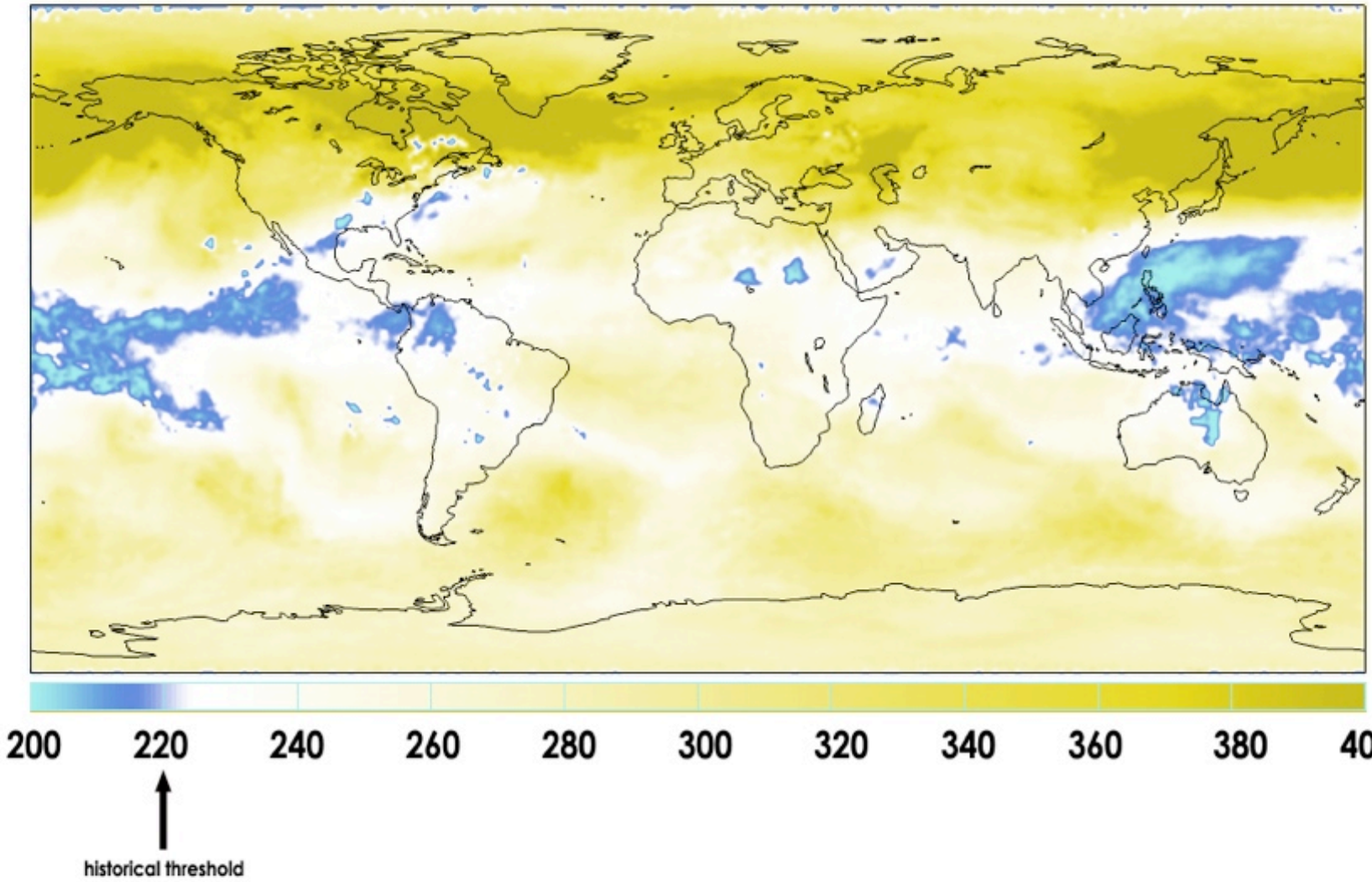


Map Making – **Ozone, total column**



Ozone Total Column 2007-01-15

3-day descending, TqJ, AVG



Community Needs Assessment:
Temperature Inversion Strength Application for Public Health

Salt Lake City

temperature inversion and public health

- Studies suggest air pollution can increase neutrophil cells in airways
  - Nobutomo, K., 1978. Air pollution and cytological changes in sputum. Lancet 1: 523–526.
  - Dragonieri, S., Musti, M., Izzo, C., Esposito, L.M., Barbaro, M.P.F., Resta,
  - O., Spanevello, A., 2006. Sputum induced cellularity in a group of traffic policemen. Sci Total Environ 367: 433–436.
  - Wardlaw, A.J., Silverman, M., Siva, R., Pavrod, I.D., Green, R., 2005. Multi-dimensional phenotyping: toward a new taxonomy for airway disease. Clinical and Experimental Allergy 35: 1254:1262.
  - Bosson, J., Pourazar, J., Forsberg, B., Adelroth, E., Sandström, T., Blomberg, A., 2008. Diesel exhaust exposure enhances the ozone–induced airway inflammation in healthy humans. EurRespir J 31: 1234–1240.

- Researcher Julie Wallace (McMaster University, consultant)

- Study using AIRS profiles suggest measurable health effects when temperature inversions occur

  "*Atmospheric remote sensing to detect effects of temperature inversions on sputum cell counts in airway diseases*", Environmental Research 110 (2010) 624–632

Community needs assessment for a TIS product

- 10 organizations contacted, 7 responses
- Organizations include government, health, industrial sectors in USA/Canada
- Members of air quality modeling community, health professionals, environmental manager in industry

USA

- US EPA CMAQ Atmospheric Model Development Branch
- Community Modeling and Analysis System Institute for the Environment, University of North Carolina
- Colorado Department of Public Health and Environment, Air Pollution Control Division

Canada

- Firestone Institute of Respiratory Health (FIRH)
- Environment Canada
- Weather Network, Canada
- Arcelor-Mittal , Hamilton, Ontario (steel manufacturer)

Three types of users identified

1. technologically capable
   air quality modeling community

2. require NRT TIS information for particular locations
   for day to day operations – health and industry professionals

3. researchers who want access to historical and current data
   includes all segments of user community

Community needs identified

air quality modelers	• data files integrated into models or for evaluation • data for large region, sub-region, city • TIS map as quick look product for selecting geographic area
health professionals	• use product for lung health and air quality research (FIRH) • TIS app, or integrated with weather report
industry	• emissions from plant a concern • uses local wind/temp information to modify plant ops • TIS map

Everyone wants:

NRT, local area, simple & easy access to information

Up Next

- **Assist with map creation and display tools for drought, vector borne disease applications**
- **Formalize map-making process with LANCE, DAAC, BEDI, GIBS**
- **Complete map development of standard products and anomalies**
- **Complete code to operationally create our L2 maps and push into GIBS**
- **Code GIBS image access into AIRS browse tool**